AN ANGULAR TOUR OF THE WORLD

OR

THE CURIOSITIES

OF

Latitude and Longitude

A BOOK FOR TEACHERS

8643

BY

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TO THE TEACHER.

THE object of this little work is to make the *subject* clear, so that it may be intelligently presented to your classes. A clear understanding of the earth's motions and the relation of the earth to the other heavenly bodies is necessary in teaching mathematical geography.

Facts belong to the physical world and *truths* to the moral and spiritual world. A teacher who has the best and highest development of the scholar in view will combine facts and truths in teaching.

Let me explain. "The world rotates on its axis once in twenty-four hours." That is a physical fact. "We must always have a cause adequate to produce an effect." That is a moral truth. "The earth's axis is inclined sixty-six and one-half degrees to the sun's path." That is a fact. "The wisdom of this arrangement is evident." That is a truth.

I believe in the concrete idea in teaching. In order to present a fact so that it may be readily seen, it should be given in a concrete form. I believe the

truth can be arrived at without wasting the mental powers in mere mathematical gymnastics.

We must understand the *principles* involved in a problem, get a bird's-eye view of it, get down to the roots of it and out to the twigs of it—*grasp it.* It is of no use to work out a problem by *rule* unless the student understands the reason for the rule.

I believe in fulness of explanation and in variety of illustration, and in arriving at knowledge by inductive reasoning; and let us forever bear in mind this truth, that "we must always have a *cause* adequate to produce an effect."

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ILLUSTRATIONS.

AN ANGULAR TOUR OF THE WORLD;

OR,

The Curiosities of Latitude and Longitude

LATITUDE........................BREADTH.
LONGITUDE......................LENGTH.

THERE is no latitude at the equator and no longitude at London (or Greenwich), these being the initial or starting-points from which latitude and longitude are measured. We may define the position of any place on the earth very accurately by giving its latitude and longitude.

The City Hall, New York, for instance, is 40° 42′ 44″ north latitude and 74° 0′ 24″ west longitude.

Yale College, New Haven, is 41° 18′ 28″ north latitude and 72° 55′ 45″ west longitude.

The State House, Boston, is 42° 21′ 28″ north latitude and 71° 3′ 50″ west longitude.

The Auditorium, Chicago, is 41° 53′ north latitude and 87° 37′ west longitude.

One of the simplest and most self-evident proofs of the rotundity or sphericity of our earth is in connection with longitude.

If the earth were flat, the sun at rising would appear at the same instant to every one west of it, say at Yokohama, Athens, London, New York, Chicago and San Francisco.

Now the fact is, that when the sun is *rising* in Australia it is *setting* in England, and it is on the meridian of (or noon at) Chicago, all at the same instant.

If we were to send a telegram from Melbourne in the early morning (sunrise) of Sunday, July 1, it would reach Chicago Saturday *noon*, June 30, the *previous day*.

Let me take you on a personally conducted tour around the world. We will travel around the earth obliquely, at an angle of 66½ degrees to the equator, crossing *every* meridian and every parallel as far as the two circles. This might be called "An Angular Tour of the World." We shall witness some very interesting phenomena.

The curiosities of latitude and longitude are simply those *phenomena* we experience by change of position. If a person living on the equator and used to seeing the sun rise and set at six o'clock every day

throughout the year were to go to latitude 66½ north (on June 21), he would see the sun at midnight. This to him would be a curiosity; it is a phenomenon of latitude.

Suppose a person living, say, at San Francisco, saw the sun set at 5 P. M., and could travel rapidly around the earth on that parallel, the sun would set at 5 P. M. for him at Pekin, China, and every other place on the parallel, provided he had adjusted his watch to the local time of the place. That is a phenomenon of longitude *and* latitude.

Now, suppose a person lived at the Arctic Circle, on, say, meridian 75 west longitude, another at the Equator, and another at the Antarctic Circle, on the same meridian; all three would have exactly the same time—their clocks would all agree.

Let me give you an analysis of the strange and complex phenomena which I call the "Curiosities of Latitude and Longitude." Three causes combine to produce these results:

First—The axial rotation of the earth (diurnal).

Second—The inclination of the axis of rotation.

Third—The earth's yearly revolution around the sun.

Did you ever watch the motions of the separate parts of a steam engine—valve, piston and valve-

gear? The motion of each is simple; each part works in harmony with, and in relation to, the other parts; the result looks complex. Just so in regard to the several motions of the earth.

Note, now, the effect of the inclination of the earth's axis, 66½ degrees, to the plane of its orbit, or 23½* to a perpendicular to the plane of the earth's orbit. The equator is inclined 23½ degrees to the apparent path of the sun, or the ecliptic. The parallelism of the axis to itself in the yearly journey is strictly maintained.

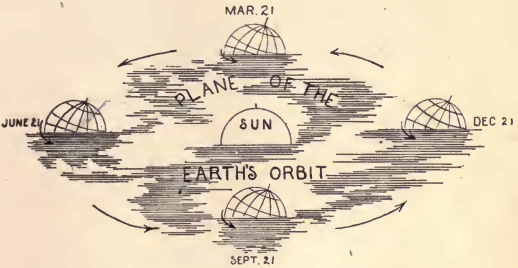
The rotation of the seasons — spring, summer, autumn and winter — is one result of this inclination, and the belting of the earth with zones is another.

In the rotation of seasons it will be observed that in both spring and fall (or autumn) seasons days and nights are *equal*† all over the globe. The night shadow is then perpendicular, whereas in the summer and winter seasons the greatest possible variation takes place in the length of day and night and in the position of the night shadow.

The plane of the ecliptic, or sun's path, is the the plane of the earth's orbit. This crosses the equator at an angle of 23½°.

* 23°-28′. † Equinox—Vernal March 21, and Autumnal Sept. 21.

The inclination of the axis to the plane of the earth's orbit is $66\frac{1}{2}°$ or $23\frac{1}{2}°$ to a perpendicular to the plane. The following diagram shows the direction of revolution and rotation, also the fixed axis of rotation:



ZONES—HOW MADE.

What makes a zone?

Did you ever watch a wood-turner at his lathe? Let him touch any point on a revolving cylinder or globe with the point of his instrument and instantly that point becomes a circle by the rotation of the cylinder on its axis, and the fixed position of the axis.

Now, if the rays of the sun touch a point north or south, say, for instance, the Arctic Circle, the diurnal

rotation of our globe makes that point a circle. As compared to the (apparent) moving sun in his yearly path, the earth's rotation is rapid.

Here is another point, say 23° 28′ north of the equator, over which the sun is vertical; the daily rotation makes this a circle again, and that circle is the Tropic of Cancer. Now, if the sun is vertical (in the zenith) at *any* point on the Tropic of Cancer, he is vertical at *every* point on that parallel; for the time being the "sun stands still," while the earth keeps on rotating, and, as the Tropic of Cancer is the limit of the sun's path north of the equator, of course it is the limit of verticality, hence marks the northern boundary of the Torrid Zone.

Observe that these circles are all concentric, parallel to each other, because of the *fixed* position of the axis of rotation. No matter how many points may be touched by the wood-turner in his work, these all become *concentric* circles, because of the fixed axis of rotation.

This explains why the same series of phenomena takes place at all points on a parallel. It is due to the stationary sun (for the time) and the rapidly rotating earth. Were the rotation slower (say a month), there would be quite an appreciable difference in the phenomena at different places on a parallel.

A parallel is a circle running around the earth, east and west, smaller than the equator, all points of which are equally distant from the equator. It is a circle parallel to the equator.

From what has been said, it will readily be seen that the zones are made practically by the sun, in combination with the rotating earth and the fixed axis of rotation.

There are five zones, as there are *five* races of men, and *five* great continents and *five* large oceans. As the Arctic and Antarctic, or Frigid Zones, bound the limit of the sun's rays at the winter solstice, so the Torrid Zone bounds the limit of his verticality at the summer solstice.

The width of the zones, therefore, corresponds with the apparent movements of the sun, the inclination of the earth's axis to a perpendicular to the ecliptic, or sun's path, being 23 degrees and 28 minutes. So we have the widths of the zones as follows:

Arctic.....................	23° 28′
North Temperate........	43° 04′
Torrid.....................	46° 56′, or twice 23° 28′
South Temperate........	43° 04′
Antarctic.................	23° 28′
	180° 00′

It will be observed by this arrangement that the greatest possible width is given to that portion of the earth best adapted to man and his needs, *i. e.*, best adapted for his occupation, namely, the two temperate zones—a belt 86° 8′ wide, or nearly half of the total of 180 degrees.

The proportion is very much larger than this when we consider the area of this belt. The value of a degree of longitude rapidly diminishes as we approach the poles—so that the area of the Frigid Zones is much smaller in proportion to their width than the Temperate or Torrid Zones.

If the earth's equator were not inclined 23° 28′ to the ecliptic or sun's path, that is, if the sun moved in the equator instead of the ecliptic, eternal cold and darkness would prevail at some places, and eternal heat and light at others. It is the inclination of the axis *plus* the rotation of that axis, together with the yearly path of the sun, that produces the compensatory balance of the *alternate* and *equal* distribution of heat and cold, light and darkness for the whole earth. I believe the earth is adapted to man and his needs. The wisdom of the inclination, rotation and revolution is evident; *nothing in Nature is accidental.* When the "Heavens and the Earth were finished" they were finished in the sense of perfection and completeness.

Suppose the axis of the earth were inclined 56½° instead of 66½° to the plane of its orbit. New Orleans would then be in the Torrid Zone, and Edinburgh would be in the Arctic Zone.

Suppose the inclination were 76½°, Greenland would then be in the North Temperate Zone, and Bombay, which is now in the Torrid, would be in the North Temperate Zone.

Now suppose the angle of the ecliptic to the equator was 30° instead of 23° 28′. The width of the zones would be as follows: Torrid, 60°; the two Frigid Zones, 30° each; the Temperate Zones, 30° each, and England would then be in the Arctic Zone and in winter would have no sun at all.

Travelers call Norway the land of the midnight sun, but this is true of *any* land beyond the 66½ parallel of latitude. On the 21st of June the sun does not set at all from the Arctic Circle to the North Pole, and on the 21st of December he does not set from the Antarctic Circle to the South Pole.

I suppose that the reason why Norway is especially designated as the "Land of the Midnight Sun" is, that Norway is accessible to travelers and is in the regular route of excursion travel, but Greenland, being within the Arctic regions, is getting to be quite as accessible, and is just as much the

"Land of the Midnight Sun" as are Sweden and Norway.

The two polar circles are the farthest limits north and south where a day can consist of *just* twenty-four hours (on June 21 and December 21) with no night. *Less than* these two points the day can *never* be twenty-four hours long. Beyond these circles the day may be anywhere from 24 hours to six months long. The two circles, therefore, mark the maximum twenty-four-hour day, or a period of twenty-four hours when the sun is above the horizon.

Let me explain this phenomenon of latitude.

The greatest length of the day for all latitudes north of the equator, occurs on June 21. The night shadow then extends in a diagonal line from one edge of the Arctic Circle, to the opposite edge of the Antarctic Circle, thus uncovering (or exposing to the sun's rays) the northern Frigid Zone, and completely covering the southern. The cut on page 28 shows the position of the night shadow for June 21. This diagonal line cuts the equator at an angle of 66½° and is 23½° from the meridian or perpendicular.

At the equator the day would be just 12 hours long, the sun would rise at 6 and set at 6; at the 55th parallel the day would be 18 hours long; sun rises at 3 and sets at 9; at the 66½ parallel, the *day* is 24

hours long and the sun neither rises nor sets, but at noon he is 47° high and at midnight on the horizon, and due north. At the 55th parallel south, the day would be now, only six hours long; sun rises at 9 and sets at 3. At the 66½ parallel south, there would be no day; sun does not rise at all. The *night* is 24 hours long.

Now as the line of the night shadow forms an angle with the meridian, equal to the angle of the sun with the equator, the greater the angle the greater will be the difference in lengths of the day and night at various latitudes, and, as the greatest angle is 23½° and the greatest difference 12 hours (at the Polar Circles) each degree would represent about 30 minutes. If, therefore, the sun were 4° north declination, there would be a difference of about two hours between the length of the day at the equator and at the Polar Circles; that is, the day would be two hours in excess of 12 at the Arctic Circle, and two hours less than 12 at the Antarctic Circle. Four degrees south declination would reverse this. Of course, at the very poles themselves a *very slight* angle would produce a day of 24 hours long and as the angle increased, the region of perpetual sunshine would increase in the one Polar Zone and correspondingly decrease in the other.

People who live on opposite sides of the earth, or

the Antipodes, have opposite latitudes, longitudes, days, nights and seasons. The Antipodal Meridian is the one removed 12 hours from your own—your Antipodes, the point on that meridian in opposite latitude to your own.

People living in the same longitude have the same NOON, and, in fact, *all* hours of the day alike. *Their clocks will all agree*, but the times of their sunrise and sunset depends on the declination of the sun and their latitude. People living on the *same parallel* of latitude have sunrise and sunset at the *same* hours relatively, *but their clocks will all differ*. The relative time of sunrise, for instance, on the 42d parallel, would be the same to all places on that parallel, although in absolute time they might be hours apart. Sunrise would be at about the same hour to people living in Boston, Albany, Buffalo, Chicago, Omaha, Pekin, Constantinople, Rome and Madrid, although these places are widely apart in absolute time.

CLOCKS ALL AGREE.	CLOCKS ALL DIFFER.
A Meridian of Longitude.	*A Parallel of Latitude.*
Latitude is measured on this line north and south.	Longitude is measured on this line east and west.
On this line the lengths of the day, time of sunrise and sunset all differ (except twice a year).	On this line the lengths of the day and time of sunrise and sunset are the same at all points.
The time at any point on this line agrees with the time at any other point. If it is XII (noon) at 66½ north, it is XII (noon) at 66½ south.	On this line time differs at every point. No two points have the same time, but the relative time of sunrise and sunset would be the same at every point.

I have stated that *all* places in the same latitude have the same seasons, length of day and night, hours of sunrise and sunset, etc., but they may not have the same climatic conditions, on account of

various physical causes, mountain ranges, ocean currents, etc. For instance, England and Labrador are nearly in the same latitude, but the equatorial currents that reach England make a mild and soft climate, while Labrador is cold and sterile.

Sea level temperatures are quite different from those of mountain tops. A mountain 15,000 feet high, even at the equator, would have a temperature about equal to that of the sea level at the Arctic Circle.

There is a great difference in the United States in the climate of the Pacific slope and that of the interior of the same latitude.

So that, although the zones are bounded by mathematically concentric circles, made practically by the sun's path, the isothermal or heat lines *curve* according to the modifying conditions mentioned.

NOON.

When the sun is on the meridian of a place (*i.e.*, when it has attained its highest altitude), it is NOON at that meridian, and at *that* meridian only. Only *one* meridian can have noon at the same instant; all others are either in A. M. or P. M. Bear in mind that a meridian runs from pole to pole, or half around the

earth; consequently the antipodal or opposite meridian must be a midnight meridian. Now, noon is a point exactly half way (sun-dial time) between sunrise and sunset, and midnight a point exactly opposite noon. Of course, in average or mean sun time the forenoon may be longer or shorter than the afternoon.

The earth turns uniformly on its axis. Noon is marching around the world with measured tread. One meridian after another is brought opposite the sun.

The period of the rotation is twenty-four hours, not a second more or less.

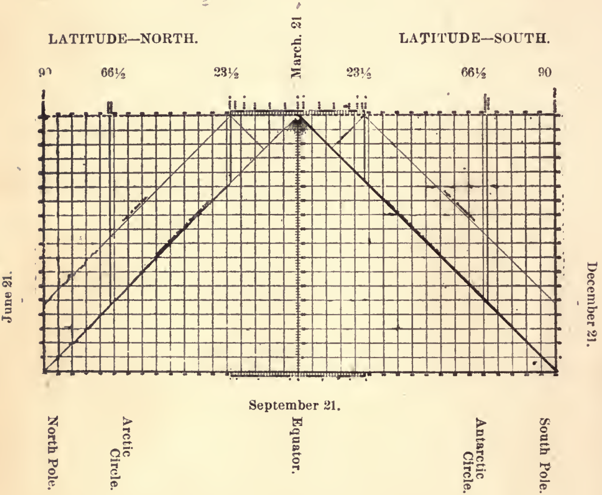
LATITUDE AND THE SUN'S MERIDIAN ALTITUDE.

Latitude will, of course, affect the sun's meridian altitude. Note the height of the sun in the diagram on page 24.

It is arranged for March and September; the sun is vertical on the equator; the angle diminishes from this (90°) to zero at either pole. At the two tropics the altitude is 66½° and at the two circles 23½° at noon.

The angle for June, the highest limit north, when the sun is vertical on the Tropic of Cancer, will

extend $23\frac{1}{2}°$ beyond the North Pole, so that at the North Pole the meridian altitude would be $23\frac{1}{2}°$. The angle for December would just touch the Arctic



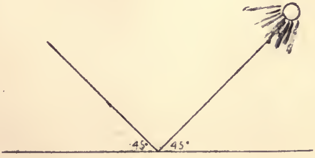
Circle; consequently the sun would not appear above the horizon from that point to the North Pole.

March 21 and September 21 the angle would just

touch either pole. The sun would, therefore, be on the horizon at midday at those points.

The sun's declination is its distance north or south of the equator.

To find the sun's meridian altitude, add its declination for that day to the co-latitude of the place (the co-latitude of a place is its latitude deducted from 90); that is, if the latitude and declination are both of the same name; but if one is north and the other south, it must be deducted instead of added. For instance, we have stated that the sun's meridian altitude for the Arctic Circle (66½° north) for the 21st of June would be 47°. The declination of the sun for this day is 23½° north, and the co-latitude of 66½° would be 23½°; this added to the declination equals 47°, which is the meridian altitude of the sun for that date. When the sun is at a meridian altitude of 45°, his rays would fall perpendicularly on the side of a hill facing the south at an angle of 45°.



Latitude does not affect TIME, except, as we have stated, the times of sunrise and sunset. I have explained how the meridian altitude of the sun can be found from the latitude and the sun's declination. Here is a simple rule for finding latitude:

LATITUDE—HOW OBTAINED.

From 90° (corrected 89°—48′) deduct the sun's observed altitude, which will equal the zenith distance (make Z. D. north if sun bears south, or south if the sun bears north). Add to zenith distance the sun's declination, if both same name, and the sum will be the latitude. If one is north and the other is south, deduct; the latitude will then be the same name as the greater number. June 21st the sun's meridian altitude at the Arctic Circle is 47°; $90 - 47 = 43$ (its Z. D.) added to 23½° (Sun's N. Dec.) = 66½°, or the latitude.

On the 21st of December the conditions we have stated for June in regard to meridian altitude north and south would be reversed. The sun is vertical on the earth only at places between the tropics. The meridian altitude of the sun is therefore never 90° or vertical (in the zenith) at any place outside of the Torrid Zone. (Never vertical in the United States.)

The sun is vertical on the equator only on the 21st of March and 21st of September; on the Tropic of Cancer on the 21st of June and on the Tropic of Capricorn on the 21st of December. On March 21 and September 21 the sun's meridian altitude equals the co-latitude of a place; for instance, the latitude of Chicago is 42° N.; the co-latitude is 90 — 42° = 48°, the meridian altitude at that date.

90 minus the altitude of a heavenly body equals its zenith distance.

90 minus the latitude of a place, equals its co-latitude or complement.

90 minus the sun's declination equals its polar distance.

Latitude affects the apparent place of the rising and setting of the sun. In March and September, or at the two equinoxes, the sun rises due east and sets due west, but as he advances northward or southward his rising and setting points advance northward or southward. On the 21st of June the sun rises 23½ degrees north of east, but for all places north of the Tropic of Cancer the sun will be south of the observer at noon. If the sun is due south at noon, he will be due north at midnight.

In summer, in the higher latitudes, the sun rises

and sets farther and farther from the east and west points until it is due north.

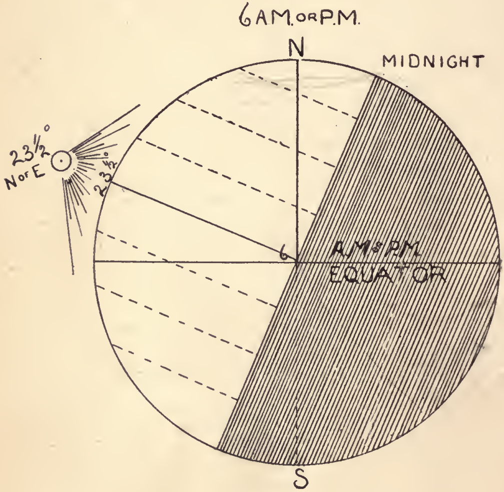


DIAGRAM SHOWING THE POINTS OF SUN'S RISING AND SETTING JUNE 21.

THE PHENOMENA OF DAY AND NIGHT.

The phenomena of day and night are phenomena belonging to both latitude and longitude. On the 21st of June, two-thirds of the night shadow on the earth is below the equator and one-third of the night shadow is above it. On the 21st of December these conditions are reversed. The shadow of night on the earth and the illuminated portions are always exactly half and half (the shadow, however, includes dawn and twilight), but the *position* of the shadow is dependent upon the time of year and latitude. The shadow is always pivoted at the equator, consequently day and night at this place are always equal. Twice a year, March and September, the shadow is perpendicular to the equator; that is, the line of the shadow is co-incident with the meridian line to which it may be pivoted. The shadow is *always* at a right angle to the sun, so that if the sun is north the shadow is south; and if the sun is south the shadow is north. Whatever angle the sun makes with the equator, a corresponding angle of the night shadow is made with the meridian. On the 21st of June and the 21st of December the line of the shadow cuts the Arctic Circle on the one hand and the Antarctic Circle on the other, and the angle is 23½°. At all other times

of the year the shadow encroaches upon the polar regions until the shadow becomes perpendicular, as stated, March 21 and September 21; so that *every* portion of the earth has an equal amount of shadow and sunshine at some time of the year from pole to pole.

There is a wonderful compensation balance in the earth. There is not a spot on its surface that does not enjoy, at some time, its equal share of the opposites of night and day, or sunshine and shadow, heat and cold, summer and winter, etc. This is especially true of sunshine. All parts of the earth have an equal amount of sunshine in the yearly distribution of sunshine.

Take, for instance, the latitude of New York at the summer solstice, June 21; New York has fifteen hours of sunshine and nine hours of shadow. The opposite latitude south, say a place in New Zealand, has nine hours of sunshine and fifteen hours of shadow. Now, take December 21; the winter solstice: New York has nine hours of sunshine and fifteen of shadow, while New Zealand has fifteen of sunshine and nine of shadow.

The law of compensation is exemplified in the distribution of heat and cold. The greatest heat is of course in the Torrid Zone, where the rays of the

sun fall perpendicularly, and the greatest cold is in the Frigid Zones, where the rays of the sun fall obliquely upon the earth. But here comes in the wonderful compensatory balance of *unequal* day and night, thus in a measure equalizing the heat.

Heat is cumulative. If more heat is received by day than can be radiated away at night, it grows and accumulates.

Thus, in the Northern Hemisphere, though the longest day is reached in June, the hottest days are in July and August.

At the equator, or in the hot-belt, days and nights are about equal in length, so that when the sun sets at 6 o'clock the earth begins to cool and the heat gathered during the day is radiated away during the twelve hours of the night.

Travelers who go to southern states in summer remark upon the coolness of the nights, notwithstanding the hot days.

Thus, this law of compensation (owing to the diurnal rotation and the inclination of the axis of rotation), makes all parts of our earth habitable and adapted to the needs of man.

Day and night must always together equal 24 hours. If the day exceeds 12 hours, the night is less than 12 hours in exact proportion. Day and night

are differential for all latitudes and 24 hours is the total.

Knowing the length of either the day or night (by day and night I mean the time between the rising and setting, or the setting and the rising sun) it is easy to get the hours of sunrise or sunset; or, knowing the hours of sunrise and sunset, it is easy to get the length of the day or night.

Double the hour of sunrise for the length of the night,
And double the hour of sunset for the length of the day;
Or take half the length of the day for the hour of sunset,
And half the length of the night for the hour of sunrise.

Co-Incident Phenomena.

The same latitude phenomena occurs in the co-incident months as follows:

May	and	July,
April	and	August,
February	and	October,
January	and	November.

In shape the earth is an oblate spheroid, *i. e.*, a sphere slightly flattened at the poles, with an excess

of matter at the equator. Its polar diameter is 7,899 and its equatorial diameter 7,925 statute miles; the value of a degree therefore at the poles is 0.7 of a mile greater than at the equator. Its circumference is 24,897 statute miles. Latitude is measured north and south from the equator, and the latitude of a place is its distance in degrees north or south of the equator. Probably sea levels in corresponding latitudes north or south of the equator are equi-distant from the earth's center.

THE NORTH POLAR STAR.

Latitude affects the height of the Pole Star, which is always at an altitude equal to the observer's latitude. The farther we go north, the *higher* the Pole Star appears above our horizon.

To an observer at the equator, the Pole Star will be on his horizon. Standing at the North Pole this star would be in his zenith. At any latitude between these two places the star will appear at a corresponding altitude. At New York, for instance, the star will appear about 41 degrees above the horizon. At the latitude of Chicago, 42 degrees.

At London it would be 52, and at Christiania, Nor-

way, the star would appear about 60 degrees above the horizon.

Every degree we move north, the North Star moves a degree higher in the heavens. It is easy to find the value of a degree of latitude, for if a ship sails about 69 miles north or south the Pole Star would move a degree north or south; hence 69 miles must be about the value of a degree of latitude. Note the table on pp. 72-73. This will show the exact value of a degree of latitude; it varies from 68.698 to 69.392, *i. e.*, expressed in English statute miles.

The diurnal (daily) rotation (apparent) of the northern heavens is contrary to the hands of a watch.

The earth is our observatory, but bear in mind it is a movable observatory. The apparent movements of the celestial bodies are due solely to the movements of our earth. The center of gravity possibly may not lie in the center of our earth. The greater land portion of the earth is in the Northern Hemisphere, and the greater part of this land portion is in the eastern half, between 15 W. and 160 E. Long.

The magnetic pole is not the North pole, but is in about 105° West Long. and 75° North Lat.; the compass will not therefore always point North. The variation must be known and corrected by the navigator.

As regards the moving circle of rotation, *East* and *West* are arbitrary terms. There is no East or West in a circle.

DIRECTION OF DIURNAL ROTATION.

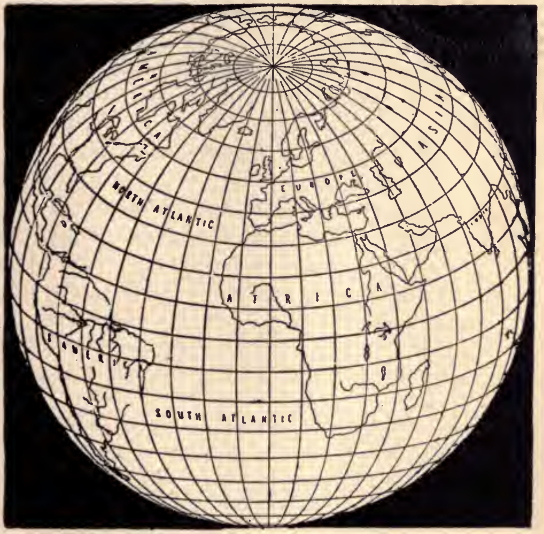
The diurnal rotation of the earth causes an apparent diurnal rotation of the heavens. In the northern

hemisphere it will be seen that the north celestial pole is the point about which the heavens revolve. Here a star has no diurnal motion. The north celestial pole is in a line with the axis of the earth. A prolonged exposure photograph of the circumpolar stars (*i. e.*, those stars which are above the observer's horizon) show concentric rings of light. Even the Pole Star itself leaves a little trail of light as it revolves around the true pole, about a degree and a half from it. The true celestial pole is that point in the heavens where the axis of the earth, if prolonged, would pierce the heavens.

Although the diurnal rotation of the earth is unvarying, this great clock having kept time through all the ages without the loss of a second, yet the axis of the earth is not (according to recent investigations and experiments) a rigid or fixed line in the earth; *i. e.*, the North Pole does not maintain an absolutely fixed position. This, of course, affects latitudes.

DAWN AND TWILIGHT.

Latitude affects the amount and duration of twilight; the duration varies with the season and the latitude, the longer twilights existing in the north-



TWILIGHT PROJECTION.

ern latitudes (in summer), and in the southern latitudes (in winter).*

The reason for this is that the greater the distance from the equator north and south, the more oblique is the line of the setting or rising sun with the horizon; consequently the greater length of time occupied in reaching the 18° limit of reflection. The sun approaching the horizon vertically, reflection would disappear much sooner than if he approached it at an oblique angle.

Dawn and twilight are of equal duration. They are both included between the setting and rising of the sun. Twilight continues until the sun is 18° below the horizon. Dawn begins when the sun is 18° from rising.

CHANGES IN THE APPEARANCE OF THE HEAVENS.

Another curiosity of latitude is the change in the appearance of the heavens at different points.

*It should be borne in mind that in speaking of summer and winter, we mean that portion of the year representing the summer and winter of the Northern Hemisphere. December is the summer of the Southern Hemisphere and June the winter season.

On the equator at latitude zero, stars will rise and set vertically, cutting the horizon at right angles. At the poles or latitude 90°, the stars would neither rise nor set, but would revolve around the pole in concentric circles at altitudes corresponding to their declinations. The moon would be visible for about two weeks, and the sun for six months at a time.

At any latitude between the equator and the poles, the stars would rise and set obliquely.

LATITUDE AFFECTS GRAVITY.

A body would weigh more at the poles than at the equator, but if weighed with ordinary weight balances the difference would not show, as the weights themselves would be affected as well as that which is weighed.

A pendulum swings faster at the poles than at the equator. A pendulum clock that would keep accurate time at the equator, would gain 3½ minutes a day at the poles; moreover, as a pendulum would swing in a true plane, the rotation of the earth would cause it to form a star marked upon the surface of the globe could it swing about the pole.

Such are some of the curiosities of latitude. We might recapitulate some of the effects, as follows:

1. Varying lengths of day and night.
2. The hours of sunrise and sunset.
3. The angle of the sun.
4. The place of the sun's rising and setting.
5. The peculiar angles of the rising and setting of stars.
6. The position of the night shadow.
7. Variation in length of degrees.
8. Height of the Pole Star.
9. The circles of perpetual apparition and occultation.
10. Twilight and dawn.
11. Gravity.
12. The pendulum.

The curiosities of latitude mentioned are those which are due solely to the motions of the earth. I have not touched on the physical aspects of latitude except incidentally.

The work is intended to show those phenomena which come within the reach and scope of Mathematical Geography.

LONGITUDE AND TIME.

LONGITUDE

is the *angular* distance between any two meridians. It is reckoned, *east* or *west*, from any given meridian, called a first or prime meridian. Meridian circles run around the earth north and south, and a meridian reaches from pole to pole. Meridian lines all converge at the poles, and cut the equator at right angles. The greatest longitude any place can have is 180°, or half around the globe. Longitude is expressed in degrees, minutes and seconds.

WHAT IS TIME?

A part of duration.

The system of those relations which any event has to any other, past, present or future; an arc cut out of the circle of eternity.

Time is personified as an old man, bald-headed, but having a forelock, and carrying a scythe and hour-glass.

Tempus (L.), *Temps* (F.), *Tempo* (P. I.), whence temporal, temporary, etc.—*Cent. Dic.*

Chronos—Time. *Chronology*—Reckoning of time.

Time has been compared to a stream, or the flow of a river; the part that goes by now will never pass again.

Time is a procession of seconds, minutes, hours and days, months, years and centuries, ever marching on.

How is time measured? What is our chronometric register? What is the standard unit?

THE EARTH OUR CLOCK.

The axial rotation of the earth once in 24 hours, or one day, gives us our exact standard of measurement.

By the word *day*, we mean the whole 24 hours, or the period of *one* rotation of the earth upon its axis.

From *dial*, *dies*, come diary, diurnal, day.—*Cent. Dic.*

Day and night must *always* equal *24*.

60 seconds = 1 minute.
60 minutes = 1 hour.
24 hours = 1 day, or period of the Earth's rotation.
24 hours = 1440 minutes, or 86,400 seconds.

The earth, in its rotation, obeys an original impulse. This movement of the earth does not come under the law of universal gravitation. When a body turns upon a true and symmetrical axis and gravity is not brought into play, the axis will maintain its unvarying position.

A gyroscope top illustrates this. When set in motion, the axis always maintains the direction in which it is placed. There may be two movements of the gyroscope top—the one a rapid rotation on its axis, the other a slow, conical movement of its axis, owing to a rotation of the top, frame and all.

The earth was set spinning with the northern end of its axis pointing to the north celestial pole, and that position it still maintains.

It is true there is a slow circular motion of the pole of the earth around the pole of the ecliptic, causing the *precession of the equinoxes*, *i.e.*, the zenith of the poles change about 20″ annually. In time, therefore, Polaris will cease to be the Pole Star. There is also a slight oscillation of the pole itself, but practically the axis maintains its true position.

Polaris, the bright polar star, is the jewel in which the axis is pivoted, though at present Polaris, strictly speaking, is 1° 16′ from the true north celestial pole. The earth turns upon its axis, or polar diameter, in

an inclined position of $23\frac{1}{2}°$, in exactly 23 hours, 56 minutes, $4\frac{9}{100}$ seconds, expressed in mean solar time, from west to east, as do all the planets.

A SIDEREAL DAY.

This is a sidereal day. It is the length of time that elapses between two successive transits of the same fixed star across a meridian.

Let not the student be confused because a sidereal day is shorter than a mean solar day.

There are exactly 24 sidereal hours in a sidereal day, and exactly 24 mean solar hours in a mean solar day, but a sidereal day expressed in mean solar time is 4 minutes shorter than a mean solar day. As regards the earth, the sun moves, while the stars do not.

The gain of mean solar over a sidereal day of 4 minutes a day, amounts to 2 hours a month, or 1 day a year. A sidereal clock (such as are used in observatories) and a mean solar clock, therefore, do not coincide, except on the 21st of March. The hands would then agree. The difference of 24 hours would not appear. Like the hands of a watch, they are not together at any hour except 12 o'clock.

The earth, in its diurnal rotation sweeps the entire circle of the heavens. All circles contain exactly

360°. The 360° of this circle are traversed in exactly 24 hours, and as $360 \div 24 = 15$, it is evident that each hour of the 24, the earth passes through just 15°.

Now the day contains 24 hours, 1440 minutes or 86,400 seconds, and the 360° contains 21,600 minutes or 1,296,000 seconds; hence the earth will pass through 15° in one hour, 15′ in one minute, and 15″ of arc in one second.

The accuracy and steadiness of the turning of the earth are so remarkable that each fractional part of the 24 hours will show an exact proportionate number of degrees, minutes and seconds of arc passed over; in fact, when the last second of the 24 hours is passed, the last second of the 1,296,000 seconds of arc is also finished.

A WONDERFUL CLOCK.

The next beat of the clock begins the first 15″ of the circle again, and *every* beat of the pendulum thereafter carries the earth through 15″ of arc.

When we consider the accuracy of this magnificent clock, we are astonished. The best time-keepers are lever escapements and chronometer balances; watches of high-class makes, with care in wearing, will run within one second per week. Tiffany of New York

has records of watches running ten months with a variation of only seven seconds.

Full chronometers are not in use for pocket wear; they are liable to be affected by any sudden motion of the wearer.

Our chronometer is liable to no accidents; it needs no oiling or cleaning; it never runs down. No clock that was ever constructed can "keep time" with the earth. This clock is adjusted to heat, cold and position. It is self-winding, never gets out of order, and is synchronized to beat with the stars. It has not lost a beat through all the ages; that is, the time of its rotation has not varied in thousands of years.

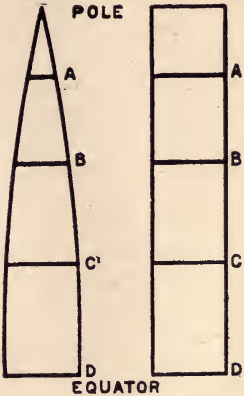
The star that is cut in two by the line in the field of the transit telescope at 8 o'clock, sidereal time, tonight, will be cut in two by the same line at precisely 8 o'clock, sidereal time, tomorrow night, and the next night, and so on through the years and ages.

The figures on p. 47 represent two sections cut from a globe and a Mercator map, respectively. The space represents one hour or 15°. It will be seen that all the parallel horizontal lines and spaces have the same value, both in time and degrees.

Time and longitude are synonymous.

It will be observed that a point at "*A*" moves very slowly compared with a point at "*D*," yet the time

occupied will be precisely the same. "*D*" represents the equator.



A point on the earth's surface at the equator moves toward the east at the rate of about 1,000 miles an hour, because the earth's equatorial circumference is about 25,000 miles, and as it takes 24 hours for one complete rotation, a point here would move, in one hour, one twenty-fourth of the circumference, or about 1,000 miles. This motion is reduced to nothing at the poles.

At the latitude of New York, the motion is about 800 miles per hour, and at the latitude of Christiania, it is reduced to 500 miles per hour; but a point on the equator passes over 15° in one hour; so does a point at the 60th parallel.

The hare at the equator will arrive at his destination at the same instant as the tortoise at the 60th parallel. All hour circles have the same value, whether they contain 60 miles or one mile to a degree.

Longitude is not synonymous with miles. It is not measured in miles, but in degrees. An hour angle contains 15°, whether it contains 900 miles (as at the equator), or one mile (as at the 89th parallel).

See table on page 70.

THE SUCCESSION OF DAYS.

Now let us see how the days follow each other. When and where does a day begin? Where does Saturday or Sunday begin? Is Sunday universal over the earth, or is it partly Sunday and partly Saturday or Monday or some other day? Is today the same day of the month at New York and New Zealand, at Bombay and at San Francisco?

Let me say that there is always day and night on the globe—that is to say, somewhere it is always perpetual day and somewhere perpetual night around the world. The sun is always waking up the morning and chasing away the shadows of night.

> "Somewhere the glorious morning hues,
> The eastern sky's adorning;
> Somewhere upon this earth of ours
> You'll find 'tis always morning."

And night is always following up the day. Where, then, does the day begin? Now suppose we begin our investigation of this subject at Chicago, near the

90th meridian of west longitude, on, say Saturday morning at 6 o'clock, we shall find the local time of New York to be 7 o'clock A. M.; 10 A. M. at the Azores in mid-Atlantic, noon at London, 7.30 P. M. at Pekin, China, while at New Zealand the day is drawing to a close. Thus it is early morning at Chicago, breakfast time in New York, dinner time in London, and supper time in Pekin all in the same day.

Suppose now we take a step to the westward of Chicago. It is 4 A. M. at San Francisco, and 1.30 A. M. at Honolulu. But all this is Saturday, a civil day twenty-four hours long, and as the civil day begins at midnight, it is evident that this particular day was born a little to the west of Honolulu. Civil days are divided into periods of twelve hours each; hence all clock dials are divided into twelve spaces of one hour each.

To a person living at Honolulu, then, Saturday has just begun; to one living in London it is noon of Saturday; to one living in New Zealand Saturday is nearly over and he is sleeping into Sunday morning; to a resident of Chicago, Sunday is eighteen hours away, while to a Londoner, it is but twelve hours away. Now it is clear that by the time Sunday gets to Honolulu, it is Monday morning at New Zealand.

Though Honolulu and New Zealand are not far apart in longitude, they are widely apart as regards latitude, the one being in north and the other in south latitude. But latitude does not affect time.

People who live on the opposite side of the earth, or Antipodes, have opposite latitudes, longitudes, days, nights and seasons.

The people of Europe have observed their Sunday while the people of the United States are sleeping, and while the people of the United States are observing their Sunday, the people of Europe are sleeping into Monday morning. It is evident, therefore, that for purposes of commerce and navigation, there must be a beginning somewhere of a day, at some point on the earth a day must begin and end, that is, the commercial civil day; Saturday, for instance, the day we have just been describing.

WHERE DOES THE DAY BEGIN?

The point opposite noon would evidently be the best TIME point, and a point farthest removed from land and civilization, the best GEOGRAPHICAL point with which to begin a new day. London being the metropolitan city of the earth, the geographical center of the land portion and the commercial center, it is

fitting also that it be the time center, and that the meridian of London should be the first meridian. A point opposite London in the Pacific ocean is a point farthest removed from this center of the world's civilization; it is therefore the best point to begin the day.

The maritime powers of the world have agreed to regard this 180th degree of longitude from London (or Greenwich) as the point where the day changes. This meridian therefore *leads the day.* Its passage under the 180th or midnight celestial meridian marks the beginning of a new day for the earth; here *today* becomes *tomorrow.* We have a new date for the month, and a new day for the week in the transition. It is here that Saturday ends and Sunday begins.

It is here, then, that Sunday was born, just to the west of Honolulu, but bear in mind that the day travels westward, therefore this new born day does not visit Honolulu until it has made the circuit of the round globe. Sunday travels west via New Zealand.

Honolulu and New Zealand are only about 30° apart in longitude, but they are a whole day apart as regards any particular day, *because* the point at which the day *changes* lies *between* them. Again, it is

evident that Sunday is a long way off from Honolulu, because that place has only just passed out of *Friday* into *Saturday*, whereas New Zealand is passing out of Saturday into Sunday.

Sunday travels west, *because* the earth travels east. Sunday must visit China, Russia, India and all of Europe, must cross the Atlantic and the United States before it can reach the Pacific and Honolulu, and no sooner does Honolulu get out of Saturday into Sunday, than Monday morning appears at New Zealand.

THE INTERNATIONAL DATE LINE.

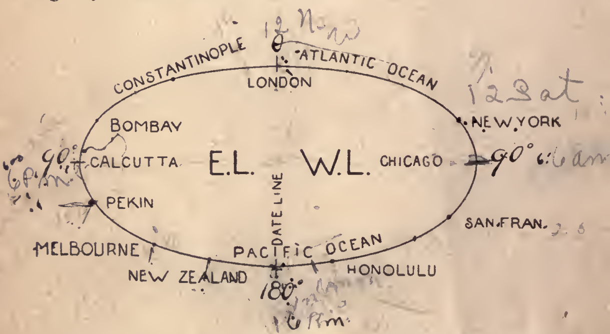
The international date line, though practically the 180th meridian, is a line drawn irregularly through the Pacific ocean, south through Behring sea; southwest past the Aleutian islands; south from Attu island on meridian 172° south, to parallel 15° north; east on 15th parallel to 150th meridian west; south on 150th meridian to parallel 15° south; west, clearing Society islands, to meridian 155° west; south to Tropic of Capricorn; southwest by south indefinitely.

The day begins here, at the 180th meridian and travels west, because the earth travels east. When it arrives at London it is about 12 hours old, at New

York about 17 hours old, and at San Francisco about 20 hours old.

When the day arrives here at the 180th meridian, it is 24 hours old; it gradually grows less and less, with the new day following, the old day diminishes and the new day increases. When noon arrives here, the end of the day is at London, with the new day following close.

The preceding day is west of the line, the succeeding day is east of it.



The longitudinal quadrants of the earth are as follows:

XII—NOON—The initial meridian—London.

VI—A.M.—The 90th meridian of W. L.—Chicag

XII—MIDNIGHT—The 180th meridian—Pacific Ocean.

VI—P.M.—The 90th meridian of E. L.—Calcutta.

These are the four cardinal points of the circle.

In studying the above diagram, it is necessary to bear in mind the point of view, which is the 180th meridian, looking through the globe to London. It does not represent the plane of any parallel, but is designed to show longitude. When XII (noon) is at London, one day and date prevail over the entire earth. If noon is either east or west of London, parts of two days are in operation. When noon is at London, there is only "a today" upon the earth. When noon leaves London, there is "a today," "a yesterday" and "a tomorrow" in operation.

Suppose, for instance, noon had arrived at Chicago. Chicago's antipodal meridian is the meridian which passes through Calcutta. Therefore, if it is noon at Chicago it is midnight at Calcutta. All of that portion of the earth east of Calcutta is therefore in tomorrow, and there people could say of that portion of the earth *west* of Calcutta (which would include of course Chicago) "*that* is in yesterday," and everyone has "a today." When it is *noon* at London only *one* day occupies the earth simply because there are 12 hours either side of noon, and 12 hours in either direction would

produce midnight. The opposite meridian from London being the 180th degree, of course, there it would be midnight. The antipodal meridian of any place is the one removed from it by 12 hours, or 180 degrees.

To find your antipodal meridian, deduct from 180 your meridian. This will give your opposite meridian in opposite longitude. For instance, what is the opposite (or antipodal) meridian to New York (75th W. L.) 180—75=105; 105 E. L. is the antipodal meridian to New York.

When noon leaves London on its travels west (everything goes west) and arrives at the 15th degree of west longitude, or, in other words, has advanced one hour to the west, the new day starting at the 180th meridian is one hour old and has advanced to the 165th degree of east longitude.

We have explained how the two places, Honolulu and New Zealand, are near together and yet practically a *whole day apart*, Honolulu being just east of the line and New Zealand just to the west of it. We have explained that the day travels *west*, so New Zealand is the first to see the new-born day. It is clear, then, if it is Friday (near midnight) at Honolulu to the *east* of the line and Sunday (near 1 A. M.) to the *west* of it, that a ship which sails from Honolulu to New Zealand, or from *east* to *west*, must sail out of

Friday into Sunday, and thereby skips the intervening day of Saturday, and gains a day, while *vice versa*, a ship which sails from New Zealand (where Sunday has begun) to Honolulu, where Friday has just ended and Saturday begun, or from *west* to *east*, must lose a day, because it has to go back into Friday. Now this change of date at the 180th meridian must not be confounded with the gain or loss of time in traveling east or west with or against the rotation of the Earth.

To gain or lose on the sun we must move our noon point. The moment we leave our position, *i. e.*, our meridian, we gain or lose, just in proportion to the number of degrees passed over.

GAIN OR LOSS OF TIME.

For instance, if we leave New York at the 75th meridian and sail *east* to London, we have gained as many hours as fifteen is contained in seventy-five, or five hours, *i. e.*, our noon in New York is five hours back of the noon we are now experiencing; or, in other words, noon of London is 7 A. M. at New York, and noon of New York is 5 P. M. of London. Here we gain absolute time, and this time is in exact proportion to the number of degrees passed over. In the other case an arbitrary line changed our date and put

us backward or forward in our dates. Moreover the crossing of this 180th meridian makes us gain the day as we go *west* and lose as we go *east*. In sailing, as regards the sun, just the reverse of this is true. We gain time in sailing east and lose time in sailing west, and in the latter case the time bears an exact proportion to the number of degrees passed over, while in the former we jump a whole day.

Every 15° passed over east or west is one hour of time, and as there are 360° in the entire circuit we should gain or lose in making the entire circuit just twenty-four hours, or one day, because $360° \div 15° = 24$.

Now we may creep over the 15° or fly over them—the result is just the same. With Jules Verne we may circumnavigate the globe in eighty days, or we may take eighty years to do it. We shall in either case lose or gain but twenty-four hours.

How shall we reconcile this gain in traveling eastward with the loss in covering the 180th meridian?

Now in sailing, say from 30° west of New Zealand to 30° east of Honolulu (for purpose of illustration let us imagine these two places to be on the 180th meridian), we have passed to the east 60°, a four hours' gain in time, but in doing this we crossed the line *going east*, so we lost a day. What have we lost or gained? Well, we have lost a day and gained

four hours. In other words we have lost twenty hours.

Suppose it was 10 A. M. of *Sunday* 30° west of the line, 30° east of it is 2 P. M. of *Saturday*. If Sunday was July 31, then we shall find our date to be Saturday, July 30, at 2 P. M., because we count back twenty hours from 10 A. M. Sunday.

So a ship which sails east from London around the world crossing this meridian, will lose a day and gain half a day. That is to say if it is noon Saturday, July 31, at London, it is *midnight* of Saturday, July 31, at this meridian.

Now at this arbitrary line or the 180th meridian, we have practically parts of *two* days in operation, while at all other places on the Earth there is but *one* day. On the line we have the midnight hours of Friday and the early hours of Sunday, the rest of the globe being occupied by Saturday. Saturday is flanked on the one side by Friday and on the other by Sunday.

I have stated that Honolulu and New Zealand were a whole day apart—practically they are—yet this is not strictly correct. The difference is not exactly a whole day, by putting it thus the student at once grasps the idea that one place is in one day of the week and the other in another day of the week.

The aim is to make it perfectly clear *why* it is Saturday in one place and Sunday in another on the earth.

CIRCUMNAVIGATING THE GLOBE.

If a ship were to circumnavigate the globe on the equator, at the rate of 900 geographical miles a day, it would take just twenty-four days to do it, because 15° multiplied by sixty, the number of miles in a degree at the equator, would produce 900, and as 15° is one twenty-fourth of the circumference it would take just twenty-four days to sail the 360°. Now as the meridians converge at the poles, the number of miles to a degree grows less and less as we approach the poles. At 60° north latitude, for instance, there are only thirty miles to a degree, consequently a ship sailing 900 miles a day will take but twelve days to circumnavigate the globe on this parallel.

Time and longitude are synonymous, but not time and distance.

We cannot measure *miles* east or west without knowing on what parallel they are to be measured. There is no time and longitude at the absolute poles. Nor is it needed. We cannot sail much nearer than 10° of the poles. The moment, however, we leave

the pole, the meridian lines have an appreciable angle, therefore, longitude can be computed.

Now the earth performs a complete rotation on its axis in exactly twenty-four hours, and in doing this goes through exactly 360°, and each fractional part of the twenty-four hours will show an exact corresponding number of degrees (of arc) passed over. It is evident from this that degrees of longitude and hours of time are convertible and interchangeable terms. Longitude means length as latitude means breadth, though latitude has nothing to do with time.

There are 21,600 minutes, or 1,296,000 seconds of arc in 360°. Also there are 1440 minutes, or 86,400 seconds of time in twenty-four hours. Now by dividing degrees by hours, or minutes by minutes, or seconds by seconds, we shall see that fifteen degrees of longitude will equal one hour of time, fifteen minutes of longitude one minute of time, and fifteen seconds of longitude one second of time.

The difference in longitude between any two places is the angular distance between their meridians, and is expressed in degrees and fractions.

Now if we knew the local time of two places, we could easily reduce this time to degrees of longitude by multiplying the number of hours by fifteen, which

would give degrees, or by adding four minutes for each degree.

On land it is easy to get simultaneous times by telegraph, but at sea this could not be done, except in some instances, as, for instance, when the Atlantic cable was laid, the time was transmitted daily from the land to the ship.

Knowing the difference in time, and consequently the longitude, it is easy to get the distance, *i. e.*, taking into account the number of miles to a degree on a given parallel. With each degree of latitude, however, the miles in a degree of longitude decrease from the equator to the pole. This is easily understood by observing how the meridian lines converge towards one another at the poles, on a globe, as we have explained.

The greatest longitude a place can have, east or west, is 180°, though sometimes it is reckoned clear around the globe from a given meridian.

THE FINDING OF LONGITUDE.

London (or Greenwich) time is the standard for navigators all over the world. It is the universal time meridian. Every ship, therefore, carries a chronometer, a finely made and nicely adjusted watch, with a compensation balance, hung and balanced so as to be affected as little as possible by the motion of the ship, and this chronometer is set to

Greenwich Mean Time.

To find his longitude, the navigator must know the *mean* time of the ship, and Greenwich *mean* time. This latter should be kept by the ship's chronometer (and the error of rate known, to be corrected in calculation). His own observations must be corrected for dip (distance from the sea level), refraction, parallax, and also for the semi-diameter of the sun (if he observes the sun). In other words, the navigator must know the hour angle of the sun. In order to get this he must know

1. His latitude.
2. The sun's altitude, and
3. The sun's declination for that day.

And when he has found *apparent* sun time, it must be corrected (by equation) to *mean* sun time; then having found the *mean* sun time of the ship, and noted the difference between it and Greenwich *mean* time, longitude is easily ascertained by converting the difference in time found into longitude.

Latitude is taken at noon, when the sun is near the meridian, but longitude observations are taken morning or evening when the sun is a few degrees above the horizon.

The instrument used is called a sextant, because it represents the sixth part of a circle.

If the navigator finds the local time of the ship to be later in the day, then he is in east longitude. If he finds it to be earlier in the day, he is in west longitude, because as the earth travels towards the east, places to the east of us will be later in the day, while those west of us will be earlier in the day. For instance, if the time of the ship be noon, and the captain finds that his chronometer says 8 A. M., then he is in 60° east longitude. But if his chronometer says 4 P. M., then he is in 60° west longitude.

We have shown how time is kept by the rotation of

the earth. Now the solar or sun day is variable, but bear in mind that it is the length of the day, plus the length of the night, that makes the whole day.

The solar day is variable. Not so the rotation of the earth. That is *forever the same.* It is the mean sun, or average sun, that makes the true day.

The time as kept by clocks is mean sun time. It is the time representing the 24 hours of the earth's rotation.

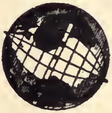
Sidereal time is time as referred to the stars. A sidereal day, expressed in sidereal hours, is the same as a mean solar day expressed in mean solar hours.

The sun travels in the ecliptic or obliquely across the earth; if he traveled in the equater, he would move uniformly, and his path could be divided into 24 equal parts, but as he moves obliquely we are obliged to make an average sun (or mean sun). Apparent, or real sun time, therefore, is not the same as *mean* sun time. The difference varies from 0 to 15 minutes.

In speaking of noon being exactly *half* way between sunrise and sunset, we mean *apparent* noon.

In closing let me say that a great many cobwebs will be brushed away by bearing in mind two facts: *First*, that the earth rotates in exactly twenty-four hours. *Second*, that it sweeps through the grand circle of 360° in just that period. And when we

come to understand that it has done this for ages without appreciable loss, we are simply astonished at the accuracy of this magnificent clock, and the wisdom that planned it.



Not only would they cut through cities, but streets and even houses, so that possibly it might be six o'clock in the parlor and seven o'clock in the kitchen of a house.

Moreover, as Captain Parker states in his "Familiar Talks on Astronomy," "standard time is not natural, and it would produce in some instances curious anomalies; for instance, suppose standard time was 30 minutes later than real sun time at a given place. On March 21st the sun would then rise at 6:30 standard time, and set at 6:30 standard time at that place; that would make the morning 5½ hours long and the afternoon 6½ hours long." Nevertheless, I am an advocate for a system of universal standard time for the earth, because it is of great benefit to travelers. And I hope all the nations of the earth will soon adopt it for all railway and steamer lines.

LONGITUDE.

The following table gives the number of miles in a degree at each parallel from the equator to the pole:

LENGTH OF A DEGREE OF LONGITUDE AT EACH PARALLEL OF LATITUDE.

LAT.	STATUTE MILE.	NAUT. MILE.	LAT.	STATUTE MILE.	NAUT. MILE.
0	69.160	60.000	45	48.986	42.498
1	69.150	59.991	46	48.126	41.752
2	69.119	59.964	47	47.251	40.992
3	69.066	59.919	48	46.362	40.223
4	68.992	59.855	49	45.459	39.439
5	68.898	59.773	50	44.542	38.643
6	68.783	59.673	51	43.611	37.835
7	68.647	59.555	52	42.667	37.016
8	68.491	59.419	53	41.710	36.186
9	68.314	59.265	54	40.740	35.344
10	68.116	59.093	55	39.758	34.491
11	67.898	58.904	56	38.763	33.628
12	67.659	58.697	57	37.756	32.755
13	67.400	58.472	58	36.737	31.872
14	67.120	58.229	59	35.707	30.979
15	66.820	57.968	60	34.666	30.076
16	66.499	57.690	61	33.615	29.164
17	66.158	57.394	62	32.553	28.242
18	65.797	57.081	63	31.481	27.311
19	65.416	56.751	64	30.399	26.372
20	65.015	56.404	65	29.308	25.425

LAT.	STATUTE MILE.	NAUT. MILE.	LAT.	STATUTE MILE.	NAUT. MILE.
21	64.594	56.039	66	28.208	24.471
22	64.154	55.657	67	27.100	23.509
23	63.695	55.258	68	25.983	22.540
24	63.216	54.843	69	24.857	21.564
25	62.718	54.411	70	23.723	20.582
26	62.201	53.962	71	22.582	19.593
27	61.665	53.497	72	21.435	18.598
28	61.110	53.016	73	20.282	17.597
29	60.536	52.518	74	19.122	16.590
30	59.944	52.005	75	17.956	15.578
31	59.334	51.476	76	16.784	14.561
32	58.706	50.931	77	15.607	13.539
33	58.060	50.370	78	14.425	12.513
34	57.396	49.794	79	13.238	11.484
35	56.715	49.203	80	12.047	10.452
36	56.016	48.597	81	10.853	9.417
37	55.300	47.976	82	9.656	8.379
38	54.568	47.340	83	8.456	7.338
39	53.819	46.690	84	7.253	6.294
40	53.053	46.026	85	6.048	5.248
41	52.271	45.348	86	4.841	4.200
42	51.473	44.656	87	3.632	3.151
43	50.659	43.950	88	2.422	2.101
44	49.830	43.231	89	1.211	1.050

LATITUDE.

The earth is an oblate spheroid, *i. e.*, its Polar diameter is about 26½ miles shorter than its Equatorial diameter.

Were the earth a perfect sphere, the miles in a degree of latitude would be the same at each parallel. They do not vary much, however, as the following table will show:

LENGTH OF A DEGREE OF LATITUDE AT EACH PARALLEL.

LAT.	STATUTE MILE.	NAUT. MILE.	LAT.	STATUTE MILE.	NAUT. MILE.
0	68.698	59.600	45	69.044	59.899
1	68.698	59.600	46	69.056	59.910
2	68.699	59.601	47	69.068	59.920
3	68.700	59.602	48	69.080	59.931
4	68.702	59.603	49	69.092	59.941
5	68.704	59.605	50	69.104	59.951
6	68.706	59.607	51	69.116	59.962
7	68.709	59.609	52	69.128	59.972
8	68.712	59.612	53	69.140	59.982
9	68.715	59.615	54	69.151	59.992
10	68.719	59.618	55	69.162	60.002
11	68.723	59.621	56	69.173	60.012
12	68.728	59.625	57	69.184	60.022
13	68.733	59.629	58	69.195	60.032
14	68.738	59.634	59	69.206	60.041
15	68.744	59.639	60	69.217	60.050

LAT.	STATUTE MILE.	NAUT. MILE.	LAT.	STATUTE MILE.	NAUT. MILE.
16	68.750	59.645	61	69.228	60.059
17	68.757	59.651	62	69.238	60.068
18	68.764	59.657	63	69.248	60.077
19	68.771	59.663	64	69.258	60.086
20	68.779	59.669	65	69.268	60.094
21	68.787	59.676	66	69.277	60.102
22	68.795	59.683	67	69.286	60.110
23	68.804	59.691	68	69.294	60.117
24	68.813	59.699	69	69.302	60.124
25	68.822	59.707	70	69.310	60.131
26	68.831	59.715	71	69.318	60.137
27	68.840	59.723	72	69.326	60.143
28	68.850	59.731	73	69.333	60.149
29	68.860	59.740	74	69.339	60.155
30	68.870	59.749	75	69.345	60.161
31	68.881	59.758	76	69.351	60.166
32	68.892	59.767	77	69.357	60.171
33	68.903	59.776	78	69.362	60.175
34	68.914	59.786	79	69.367	60.179
35	68.925	59.796	80	69.371	60.183
36	68.936	59.806	81	69.375	60.186
37	68.947	59.816	82	69.378	60.189
38	68.959	59.826	83	69.381	60.192
39	68.971	59.836	84	69.384	60.194
40	68.983	59.846	85	69.387	60.196
41	68.995	59.856	86	69.389	60.198
42	69.007	59.866	87	69.390	60.199
43	69.019	59.877	88	69.391	60.200
44	69.031	59.888	89	69.392	60.201

To convert nautical miles into statute miles, multiply nautical miles by 1.15266.

To convert statute miles into nautical miles, divide statute miles by 1.15266.

A nautical or sea mile is the length of a minute of longitude at the equator at the level of the sea.

The circumference of the earth contains 131,459,328 feet $\div$ 360° $\times$ 60 = length of a knot = 6086.+ feet.

The value of a degree of longitude at the equator is 60 geographical or 69⅙ English miles. To ascertain the distance between any two places on a globe or map on a globular projection, take the distance between the two places with a thread or the edge of a piece of paper, apply this to the equator, and get the exact number of degrees, then multiply by 60 or 69⅙, as the case may be.

Angular Measurement.

$60'' = 1'$.
$60' = 1°$.
$30° = 1$ Sign.
$90° = 1$ Quadrant.
4 Quadrants, or $360° = 1$ Circle.

To Convert Longitude into Time, divide degrees, minutes and seconds by 15, or mul-

tiply by 4 and the result will be in minutes and fractions of a minute. For example:

$$\begin{array}{r} 86^\circ - 24' - 30'' \\ 4 \\ \hline 60\overline{)\ 349^{m} \text{ and } \tfrac{38}{60}} \\ \hline 5 \quad 49 \quad 38 \end{array}$$

To Convert Time into Longitude,

multiply by 15, or divide the time reduced to minutes by 4. For example: $5^{h} - 49^{m}\ 38^{s} = 349^{m}$ and $\frac{38}{60} \div 4 = 87^\circ - 24' - 30''$.

LATITUDE AND LONGITUDE OF THE PRINCIPAL MARITIME CITIES OF THE WORLD.—UNITED STATES.

	LAT. N.	LONG. W.	
Boston, Mass	42°-21′-28″	71°- 3′-50″	State House.
Baltimore, Md.	39 -17 -48	76 -36 -59	Wash't Monument.
Charleston, S. C.	32 -41 -44	79 -52 -58	Light House.
New York, N. Y.	40 -42 -44	74 - 0 -24	City Hall.
Chicago, Ill.	41 -53 - 0	87 -37 - 0	Auditorium Tower
Philadelphia, Pa.	39 -56 -53	75 - 9 - 3	State House.
New Haven, Conn	41 -18 -28	72 -55 -45	Yale College.
Providence, R. I.	41 -49 -26	71 -24 -19	Unitarian Church.
Portland, Me.	43 -39 -28	70 -15 -18	Custom House.
Jacksonville, Fla	30 -19 -43	81 -39 -14	Methodist Church.
Key West, Fla.	24 -32 -58	81 -48 - 4	Light House.
Washington, D. C.	38 -53 -20	77 - 0 -36	Capitol.
New Orleans, La.	29 -57 -46	90 - 3 -28	U. S. Mint.
San Francisco, Cal.	37 -47 -55	122 -24 -32	
San Diego, Cal.	32 -43 - 6	117 - 9 -40	
San Lucas, Cal.	22 -53 -21	109 -54 -41	

	LAT. N.	LONG. W.	
Santiago, Cuba	20°- 0′-16″	75°-50′-40″	
City of Mexico	19 -26 - 1	96 - 6 -39	
Point Barrow, Alaska	71 -27 - 0	156 -15 - 0	
Seattle, Wash	47 -35 -54	122 -19 -59	
Panama, C. A	8 -57 - 6	79 -32 -12	
Port Royal, Ja	17 -55 -56	76 -50 -38	
	S.	W.	
Rio De Janeiro, Brazil	22 -54 -24	43 -10 -21	Observatory.
Cape Horn, T. D. F	55 -58 -41	67 -16 -15	
Valpariso, Chili	33 - 1 -53	71 -38 -42	
	S.	E.	
Melbourne, Aus	37 -49 -53	144 -58 -32	Observatory. [Sta.
Hobart Town, Tas	42 -53 -25	147 -20 - 7	Transit of Venus
Wellington, N. Z	41 -16 -57	174 -46 -22	Observatory.
	N.	W.	
Cape Hecla	82 -54 - 0	64 -45 - 0	Extreme North.
Cape Columbia	83 - 7 - 0	70 -20 - 0	
Cape York, Greenland	75 -55 - 0	65 -30 - 0	Extreme North.
Montreal, P. Q	45 -30 -24	73 -33 - 4	Cathedral.
Quebec	46 -48 -32	71 -12 -19	Citadel.

	LAT. N.	LONG. W.	
Azores, Fayal	38°-31′-45″	28°-38′-54″	
Canaries, Teneriffe	28 -35 -25	16 - 8 - 6	
Greenwich, Eng	51 -28 -38	0 - 0 - 0	Observatory.
Dublin, Ireland	53 -23 -13	6 -20 -30	Observatory.
	N.	E.	
Christiania, Norway	59 -54 -44	10 -43 -35	Observatory.
Stockholm, Sweden	59 -20 -35	18 - 3 -30	Observatory.
St. Petersburg, Russia	59 -56 -30	30 -19 -22	Observatory.
Berlin, Germany	52 -30 -17	13 -23 -44	Observatory.
	N.	E.	
Copenhagen, Denmark	55 -41 -14	12 -34 -47	Observatory.
Amsterdam, Holland	52 -22 -30	4 -53 - 4	Church Tower.
Antwerp, Belgium	51 -12 -28	4 -24 -44	Observatory.
Paris, France	48 -50 -11	2 -20 -14	Observatory.
	N.	W.	
Lisbon, Portugal	38 -42 -31	9 -11 -10	Observatory.
	N.	E.	
Marseilles, France	43 -18 -22	5 -23 -43	Observatory.
Rome, Italy	41 -53 -54	12 -38 -40	Observatory.

	LAT. N.	LONG. E.	
Trieste, Austria....	45°-28′-51″	13°-46′- 0″	Observatory.
Athens, Greece	37 -58 -10	23 -43 -55	Observatory.
Constantinople, Turkey.....	41 - 0 -30	29 - 0 -55	Seraglio P't L't.
Odessa, Russia...............	46 -28 -36	30 -45 -35	Observatory.
Alexandria, Egypt..........	31 -11 -43	29 -51 -40	Ennostos P't L't.
	S.	E.	
Cape of Good Hope, Africa	34 -21 -12	18 -29 -30	Light House.
Zanzibar, Africa.............	6 - 9 -43	39 -11 -11	Eng. Consulate.
	N.	E.	
Bombay, India.........	18 -53 -45	72 -48 -58	Observatory.
Colombo, Ceylon..............	6 -55 -40	79 -50 -29	Gov'nt Flagstaff.
Canton, China................	23 - 6 -35	113 -16 -34	
Yokohama, Japan.............	35 -26 -24	139 -39 -13	Eng. Sig. House.
	N.	W.	
Hawaii, S. Is.	19 -38 -26	156 - 0 -15	
Honolula, S. Is....	21 -17 -55	157 -52 - 0	Reef Light.

SUN'S DECLINATION.

Jan.	1	23- 2	S.	July	1	23- 7	N.
"	15	21- 0	"	"	15	21-34	"
"	21	19-56	"	"	21	20-31	"
"	30	17-41	"	"	30	18-34	"
Feb.	1	17-08	"	Aug.	1	17-56	"
"	15	12-40	"	"	15	14- 2	"
"	21	10-34	"	"	21	12- 0	"
"	28	8- 0	"	"	30	9- 0	"
March	1	7-33	"	Sept.	1	8-17	"
"	15	2- 8	"	"	15	3- 1	"
"	21	0-15	N.	"	21	0-42	"
"	30	3-48	"	"	30	2-50	S.
April	1	4-35	"	Oct.	1	3- 4	"
"	15	9-48	"	"	15	8-25	"
"	21	11-52	"	"	21	10-27	"
"	30	14-48	"	"	30	13-43	"
May	1	15- 5	"	Nov.	1	14-22	"
"	15	18-52	"	"	15	18-27	"
"	21	20-10	"	"	21	19-53	"
"	30	21-48	"	"	30	21-39	"
June	1	22- 1	"	Dec.	1	21-47	"
"	15	23-19	"	"	15	23-16	"
"	21	23-28	"	"	21	23-27	"
"	30	22- 8	"	"	30	23-13	"